

Reduction of Background Noise in the
NASA Ames 40- by 80- Foot Wind Tunnel

Stephen M. Jaeger*

Christopher S. Allen*

Sterling Federal Systems
NASA Ames Division
Moffett Field, California

and

Paul T. Soderman†

NASA Ames Research Center
Moffett Field, California

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Abstract

Background noise in both open-jet and closed wind tunnels adversely affects the signal-to-noise ratio of acoustic measurements. To measure the noise of increasingly quieter aircraft models, the background noise will have to be reduced by physical means or through signal processing. In a closed wind tunnel, such as the NASA Ames 40- by 80-Foot Wind Tunnel, the principle background noise sources can be classified as: 1) fan drive noise 2) microphone self-noise 3) aerodynamically induced noise from test-dependent hardware such as model struts and junctions, and 4) noise from the test section walls and vane set. This paper describes the steps taken to minimize the influence of each of these background noise sources in the 40 x 80.

* Aeroacoustics Engineer, Member AIAA.

† Group Leader, Aeroacoustics and Test Techniques, Associate Fellow AIAA.

At low frequencies and at test section velocities lower than 120 knots, the wind tunnel fans are the dominant source of tonal and broadband noise. In the 40 x 80 most of this noise is observed at frequencies below 500 Hz.¹ Sound intensity mapping of the test section, diffuser, and contraction cone, was done with the drive fans at flat pitch. The results indicated that most of the fan noise tends to propagate upstream from the diffuser except for frequencies below 500 Hz where sound propagates equally from the contraction cone and the diffuser. The diffuser acts like a horn to allow efficient radiation of noise into the test section. The contraction cone reflects noise because of the relatively abrupt area change. Acoustic treatment on the vane sets upstream of the contraction cone also attenuate some of the fan noise.

Part of the solution for reducing the drive noise of the wind tunnel is to lower the fan speed below 180 RPM and control the test section velocity with the fan blade angle.² Recent tests indicate that the effect of varying the fan angle is most advantageous at low test section velocities but has little effect at high velocities where the background noise is dominated by the microphone self-noise.

Microphone self-noise appears to be the main source of background noise for measurements above 500 Hz.² Microphone self noise comes from several sources including: 1) boundary layer noise on the microphone, 2) noise created by onset turbulence striking the microphone³ and 3) high frequency nose cone tones. One solution was the development of the FITE (Flow-Induced Tone Eliminator) nose cone which eliminated high frequency tones generated at the nose cone screen.⁴

Coherence measurements were made between two closely spaced in-flow microphones in the test section. The results show high coherence for frequencies below 500 Hz which is attributed to the wind tunnel fan tones. The maximum level of the coherence drops with increasing wind tunnel speed indicating the presence of increased incoherent self-noise.⁵ The phase between the two microphones is also ambiguous above 500 Hz indicating the presence of uncorrelated self-noise at each microphone.

Noise created by test hardware in the test section have a wide range of characteristics depending on the particular source. Noise from microphone struts, model struts etc. have haystack-shaped frequency spectra, but sharp tones may also result from steady vortex shedding from cylinders and other objects.⁶ During a test of various microphone strut designs, it was found that elimination of strut braces and junctions reduced the background noise significantly. This lead to the development of struts with maximum thickness airfoils

such as the McMasters-Henderson airfoil⁷ which is designed to delay transition and eliminate laminar flow separation at high Reynolds numbers. Maximum thickness airfoils are strong and can often be used without braces.

Various signal processing methods have been employed for discriminating against background noise to increase the signal-to-noise ratio. The paper will include some results from cross-spectrum measurements, multiple-element arrays, and time-delayed dual-microphone measurements. With careful attention devoted to elimination of background noise sources and utilizing advanced signal processing methods, the signal-to-noise ratio in the 40- by 80- Foot Wind Tunnel test section will be maximized for the future needs of aeroacoustic wind tunnel testing.

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